Chemistry 20–30

Program Outcomes

Consultation Draft

June 2003

This consultation draft of the program outcomes was initiated based on information collected during the secondary science needs assessment conducted in 1998. It was developed under the guidance of the Alberta Learning Science Interbranch Team with advice from the Science 10–12 Advisory Committee made up of teachers and education stakeholders from across the province. This consultation draft is posted on the Alberta Learning Web site at www.learning.gov.ab.ca/k_12/curriculum/bySubject/science/default.asp, with an electronic questionnaire. Consultation forums will provide additional opportunities to gather feedback.

CHEMISTRY 20

Chemistry 20 consists of four units of study:

A. The Diversity of Matter and Chemical Bonding
B. Forms of Matter: Gases
C. Matter as Solutions, Acids and Bases
D. Quantitative Relationships in Chemical Changes

Attitude Outcomes for Chemistry 20

Students will be encouraged to develop positive attitudes that support the responsible acquisition and application of knowledge related to science and technology. The following attitude outcomes are to be developed throughout the Chemistry 20 program, in conjunction with the outcomes for Knowledge, Science, Technology and Society (STS) and Skills in each unit.

Interest in Science

Students will be encouraged to:
Show interest in science-related questions and issues and confidently pursue personal interest and career possibilities within science-related fields, e.g.,

- *appreciate how scientific problem solving and new technologies are being developed and implemented*
- *appreciate the usefulness of models and theories in helping to explain the structure and behaviour of matter*
- *investigate careers in fields such as food science, engineering, laboratory technology, environmental chemistry, agriculture, water treatment and forensic science*
- *develop an interest in the role of chemistry in daily life*
- *develop a questioning attitude and a desire to understand more about matter*
- *express interest in science and technology topics not directly related to the students' formal studies*
- *develop an awareness of the relationship between chemical principles and applications of chemistry*
- *identify industrial, commercial and household processes and products and associated careers that require a knowledge of quantitative analysis*

Mutual Respect

Students will be encouraged to:
Appreciate that scientific understanding evolves from the interaction of ideas involving people with different views and backgrounds, e.g.,

- *recognize that theories develop as a result of the sharing of ideas by many scientists*
- *trace, from a historical perspective, how the observations and experimental work of many individuals led to modern understandings of matter*
- *value traditional knowledge of common solutions and substances*
- *research the role of chemistry in the International Space Station project*
- *investigate how early peoples developed recipes for common foods, cleaners and remedies*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

Scientific Inquiry

Students will be encouraged to:
Seek and apply evidence when evaluating alternative approaches to investigations, problems and issues, e.g.,

- *develop curiosity about the nature of chemistry*
- *tolerate the uncertainty involved in providing explanations and theoretical definitions*
- *appreciate the limited nature of evidence when interpreting observed phenomena*
- *appreciate that scientific evidence is the foundation for generalizations and explanations about chemistry*
- *value the role of precise observation and careful experimentation in learning about chemistry*

Collaboration

Students will be encouraged to:
Work collaboratively in planning and carrying out investigations and in generating and evaluating ideas, e.g.,

- *assume a variety of roles within a group, as required*
- *evaluate the ideas of others objectively*
- *accept responsibility for any task that helps the group complete an activity*
- *seek the points of view of others and consider a multitude of perspectives*

Stewardship

Students will be encouraged to:
Demonstrate sensitivity and responsibility in pursuing a balance between the needs of humans and a sustainable environment, e.g.,

- *willingly evaluate the impact of their own choices or the choices scientists make when they carry out an investigation*
- *remain critical-minded regarding the short- and long-term consequences of human actions*
- *consider a variety of perspectives when addressing issues, weighing scientific, technological, economic, political and ecological factors*

Safety

Students will be encouraged to:
Show concern for safety in planning, carrying out and reviewing activities, e.g.,

- *treat equipment with respect and carefully manipulate materials*
- *value the need for safe handling and storage of chemicals*
- *recognize the significant role that chemical researchers and the chemical industry play in identifying risks and developing guidelines in safe exposure, e.g., Responsible Care®*
- *dispose of used materials appropriately*
- *use minimal quantities of chemicals when performing experiments*
- *assume responsibility for the safety of all those who share a common working environment, by cleaning up after an activity and disposing of materials in a safe place according to safety guidelines*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

Unit A: The Diversity of Matter and Chemical Bonding

Themes: Diversity and Matter

Overview: Concepts, models and theories are often used in interpreting and explaining observations and in predicting future observations. The major focus of this unit is to relate theories about bonding to the properties of matter and to develop explanations and descriptions of structure and bonding through scientific models. Students learn more about the diversity of matter from selected examples of organic compounds.

This unit builds on:
- Science 9, Unit 5: Chemical Properties of Change
- Science 10, Unit C: Energy and Matter in Chemical Change

This unit provides an introduction to Chemistry 30, Unit A: Thermochemical Changes, Unit B: Electrochemical Changes and Unit C: Chemical Changes of Organic Compounds. This unit will require approximately 20% of the allotted time for Chemistry 20.

Links to Mathematics:

Topics:	These topics may be found in the following courses:
• plotting linear and non-linear data	Pure Mathematics 10, specific outcome 3.1
• rational equations that reduce to linear equations	Pure Mathematics 10, specific outcome 2.7; Applied Mathematics 10, specific outcomes 1.2, 1.3 and 5.1
• experimental results and experimental error	Applied Mathematics 20, specific outcomes 6.2, 6.3 and 6.4

Focusing Questions: Why do some substances dissolve easily, while others do not? Why do different substances have different boiling and melting points and heats of fusion and vaporization? How can models increase understanding of bonding?

General Outcomes: There are two major outcomes in this unit.

Students will:
1. Describe the role of modeling, evidence and theory used in explaining and understanding the structure, chemical bonding and behaviour of ionic compounds.
2. Describe the role of modeling, evidence and theory used in explaining and understanding the structure, chemical bonding and behaviour of molecular substances.

Key Concepts: The following concepts are developed in this unit and may also be addressed in other units at other levels. The intended level and scope of treatment is defined by the learning outcomes.
- chemical bond
- ionic bond
- polarity
- covalent bond
- valence electron
- hydrogen bond
- electronegativity
- intermolecular bonding
- electron dot diagrams
- Lewis structures
- valence-shell electron-pair repulsion (VSEPR) theory

General Outcome 1: Describe the role of modeling, evidence and theory used in explaining and understanding the structure, chemical bonding and behaviour of ionic compounds.

Outcomes for Knowledge

Students will:

20–A1.1k Review principles for assigning names to ionic compounds

20–A1.2k Explain why formulas for ionic compounds refer to the simplest whole number ratio of ions that result in a net charge of zero

20–A1.3k Explain how a chemical bond results from the simultaneous attraction of electrons by two atomic nuclei

20–A1.4k Use the periodic table to support and explain bonding theory, describe bonding as a continuum ranging from complete electron transfer to equal sharing of electrons

20–A1.5k Define valence electron, electronegativity and ionic bond

20–A1.6k Draw or build models of ionic solids and analyze the structures

Outcomes for Science, Technology and Society (Emphasis on the nature of science)

Students will:

20–A1.1sts Explain that the goal of science is knowledge about the natural world (**NS1**), e.g.,

- *identify everyday processes and products in which ionic compounds are significant, such as in the composition of household products, food and life processes*

20–A1.2sts Explain that scientific knowledge and theories develop through hypotheses, collection of evidence through experimentation and the ability to provide explanations (**NS2**), e.g.,

- *describe how an understanding of electronegativity contributes to the knowledge of relative bond strength, melting points and boiling points of ionic substances*

20–A1.3sts Explain that scientific knowledge may lead to the development of new technologies and that new technologies may lead to scientific discovery (**ST4**), e.g.,

- *explain how scientific research and technology interact in the production and distribution of beneficial materials, including semiconductors, ceramics and composite materials*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 1: Describe the role of modeling, evidence and theory used in explaining and understanding the structure, chemical bonding and behaviour of ionic compounds.

Skill Outcomes (Focus on scientific inquiry)

Initiating and Planning

Students will:

20–A1.1s Ask questions about observed relationships and plan investigations of questions, ideas, problems and issues by

- designing an investigation to determine the properties of ionic compounds (solubility, conductivity, melting point) (**IP–NS4**) [**ICT C1–4.2**]; and, e.g., by
- *researching the question "Should all scientific research have a practical application?"* (**IP–NS1**) [**ICT C2–4.1**]
- *designing an experiment to explore the formation of ionic compounds* (**IP–NS2**) [**ICT C2–4.2**]

Performing and Recording

Students will:

20–A1.2s Conduct investigations into relationships among observable variables and use a broad range of tools and techniques to gather and record data and information by

- drawing electron dot diagrams and building models of ionic solids (**CT–NS2**) [**ICT P3–4.3**]; and, e.g., by
- *performing an investigation to illustrate properties of ionic compounds* (**IP–STS2**) [**ICT C6–4.1**]
- *using the periodic table to make predictions about bonding and nomenclature* (**PR–NS1, AI–NS1**) [**ICT C6–4.2**]
- *using model building software to collect and integrate information on the structure of ionic crystals* (**PR–NS4**) [**ICT C7–4.3**]

Analyzing and Interpreting

Students will:

20–A1.3s Analyze data and apply mathematical and conceptual models to develop and assess possible solutions by

- analyzing experimental data to determine the properties of ionic compounds (**AI–NS6**) [**ICT P2–4.1**]; and, e.g., by
- *using data from various sources to predict the strength of bonds between ions* (**PR–NS1, AI–NS2**) [**ICT C1–4.1**]

Communication and Teamwork

Students will:

20–A1.4s Work as members of a team in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results by

- critically analyzing models of ionic compounds built by others (**CT–NS3**) [**ICT P6–4.1**]

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 2: Describe the role of modeling, evidence and theory used in explaining and understanding the structure, chemical bonding and behaviour of molecular substances.

Outcomes for Knowledge

Students will:

20–A2.1k Review principles for assigning names to molecular substances
20–A2.2k Explain why the formulas for molecular substances refer to the number of atoms of each constituent element
20–A2.3k Relate electron pairing to covalent bonds
20–A2.4k Build models depicting the structure of simple covalent molecules, including selected organic compounds
20–A2.5k Draw electron dot diagrams of atoms and molecules, writing structural formulas for molecular substances and using Lewis structures to predict bonding in simple molecules
20–A2.6k Apply VSEPR theory to predict molecular shapes
20–A2.7k Relate properties of substances, e.g., melting and boiling points, heats of fusion and vaporization, to the predicted intermolecular bonding in the substance
20–A2.8k Illustrate, by drawing or building models, the structure of simple molecular substances
20–A2.9k Explain intermolecular forces, London (dispersion) forces, dipole-dipole attractions and hydrogen bonding
20–A2.10k Determine the polarity of a molecule based on simple structural shapes and unequal charge distribution

Outcomes for Science, Technology and Society (Emphasis on the nature of science)

Students will:

20–A2.1sts Explain that scientific knowledge and theories develop through hypotheses, the collection of evidence through experimentation and the ability to provide explanations (**NS2**), e.g.,

- *relate chemical properties to their predicted intermolecular bonding by investigating melting and boiling points*

20–A2.2sts Explain that scientific knowledge is subject to change as new evidence comes to light and as laws and theories are tested and subsequently restructured, revised or reinforced (**NS4, ST4**), e.g.,

- *explain how scientific research and technology interact in the production and distribution of beneficial materials, e.g., polymers, household products, life processes, solvents*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 2: Describe the role of modeling, evidence and theory used in explaining and understanding the structure, chemical bonding and behaviour of molecular substances.

Skill Outcomes (Focus on scientific inquiry)

Initiating and Planning

Students will:

20–A2.1s Ask questions about observed relationships and plan investigations of questions, ideas, problems and issues by

- stating a hypothesis and making a prediction about the melting or boiling point of molecular substances based on attractive forces **(IP–NS3)** **[ICT C6–4.1, 4.2]**

Performing and Recording

Students will:

20–A2.2s Conduct investigations into relationships among observable variables, and use a broad range of tools and techniques to gather and record data and information by:

- carrying out an investigation to determine the melting or boiling point of a molecular substance **(PR–NS2)** **[ICT P2–4.1]**; and, e.g., by
- *using a thermometer and a conductivity apparatus to collect data* **(PR–ST3)** **[ICT F1–4.2]**
- *carrying out an investigation to compare the properties of molecular compounds* **(PR–STS2)** **[ICT P–4.1]**

Analyzing and Interpreting

Students will:

20–A2.3s Analyze data and apply mathematical and conceptual models to develop and assess possible solutions by:

- graphing and analyzing data, for trends and patterns, on the melting and boiling points of a related series of molecular substances **(AI–NS2)** **[ICT C6–4.3]**

Communication and Teamwork

Students will:

20–A2.4s Work as members of a team in addressing problems, and apply the skills and conventions of science in communicating information and ideas and in assessing results by

- objectively evaluating and analyzing models and graphs constructed by others **(CT–NS3)** **[ICT C6–4.5]**; and, e.g., by
- *researching the ways scientists develop and analyze new materials* **(PR–NS1)** **[ICT C7–4.2]**

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

Unit B: Forms of Matter: Gases

Themes: Matter, Change and Energy

Overview: Students expand their knowledge of the nature of matter through the investigation of the properties and behaviour of gases.

This unit builds on:
- Science 9, Unit B: Matter and Chemical Change
- Science 10, Unit A: Energy and Matter in Chemical Change

This unit provides an introduction to Chemistry 30, Unit D: Equilibrium. This unit will require approximately 12% of the time allotted for Chemistry 20.

Links to Mathematics:

Topics:	These topics may be found in the following courses:
• rational equations that reduce to linear equations	Pure Mathematics 10, specific outcome 2.7; Applied Mathematics 10, specific outcomes 1.2, 1.3 and 5.1
• graphical and technological methods to solve nonlinear equations	Pure Mathematics 10, specific outcomes 3.1 and 4.2, and Pure Mathematics 20, specific outcomes 3.1 and 6.4; Applied Mathematics 10, specific outcomes 3.1, 3.2, 3.3 and 5.1, and Applied Mathematics 20, specific outcomes 2.1, 2.3, 2.4 and 2.5
• experimental results and experimental error	Applied Mathematics 20, specific outcomes 6.2, 6.3 and 6.4

Focusing Questions: How do familiar observations of gases relate to specific scientific models describing the behaviour of gases? What is the relationship between the pressure, temperature, volume and amount of a gas?

General Outcomes: There is one major outcome in this unit.

Students will:
1. Explain molecular behaviour using models of the gaseous state of matter.

Key Concepts: The following concepts are developed in this unit and may also be addressed in other units at other levels. The intended level and scope of treatment is defined by the learning outcomes.
- Kelvin temperature scale
- real and ideal gases
- Law of combining volumes
- standard temperature and pressure (STP)
- standard atmospheric temperature and pressure (SATP)
- absolute zero

General Outcome 1: Explain molecular behaviour using models of the gaseous state of matter.

Outcomes for Knowledge

Students will:

20–B1.1k Describe and compare the behaviour of real and ideal gases in terms of kinetic molecular theory

20–B1.2k Demonstrate the ability to convert between the Celsius and Kelvin temperature scales

20–B1.3k Explain the law of combining gases

20–B1.4k Illustrate how Boyle's, Charles' and combined gas laws are related to the ideal gas law

- express atmospheric pressure using mm of mercury, atm, bar (=100kPa) and kPa
- perform calculations based on the ideal gas law (PV=nRT) under a variety of conditions, i.e., standard temperature and pressure (STP), standard ambient temperature and pressure (SATP)

Outcomes for Science, Technology and Society (Emphasis on the nature of science)

Students will:

20–B1.1sts Explain that science provides a conceptual and theoretical basis for predicting, interpreting and explaining natural and technological phenomena (**NS5**), e.g.,

- *describe how the development of technologies capable of precise measurements of temperature and pressure led to a better understanding of gases and the formulation of the gas laws, e.g., thermocouples, thermisters, Boruden gauges*

20–B1.2sts Explain that the goal of science is knowledge about the natural world (**NS1**), e.g.,

- *describe examples of natural phenomena and processes and products that illustrate the properties of gases, e.g., breathing, diffusion, weather, hot air balloons, scuba diving equipment, automobile air bags, gas turbines, internal combustion engines*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 1: Explain molecular behaviour using models of the gaseous state of matter.

Skill Outcomes (Focus on scientific inquiry)

Initiating and Planning

Students will:

20–B1.1s Ask questions about observed relationships and plan investigations of questions, ideas, problems and issues by

- stating hypotheses and making predictions based on information about the pressure, temperature and volume of a gas **(IP–NS3)** **[ICT C1–4.2]**; and, e.g., by
- *designing an experiment to illustrate Boyle's and/or Charles' gas laws* **(IP–NS2)**
- *designing an investigation to determine the universal gas constant* (*R*) *or absolute zero* **(IP–NS2)**

Performing and Recording

Students will:

20–B1.2s Conduct investigations into relationships among observable variables and use a broad range of tools and techniques to gather and record data and information by

- performing an experiment to illustrate the gas laws that identify and control variables **(PR–NS2)** **[ICT C6–4.2]**; and, e.g., by
- *using thermometers, balances and other measuring devices effectively to collect data on gases* **(PR–NS3)** **[ICT F1–4.2]**
- *using library and electronic research tools to collect information on real and ideal gases and applications of gases, e.g., hot air and weather balloons* **(PR–NS1, PR–ST1)** **[ICT C1–4.2]**
- *performing an investigation to determine molar mass from gaseous volume* **(PR–NS2, AI–NS6)** **[ICT C6–4.1]**

Analyzing and Interpreting

Students will:

20–B1.3s Analyze data and apply mathematical and conceptual models to develop and assess possible solutions by

- drawing and interpreting graphs of experimental data that relate pressure and temperature to gas volume **(AI–NS2)** **[ICT C6–4.3]**; and, e.g., by
- *identifying the limitations of measurement* **(AI–NS4)** **[ICT C6–4.5]**
- *identifying a gas based on an analysis of experimental data* **(AI–NS2)** **[ICT C6–4.1]**

Communication and Teamwork

Students will:

20–B1.4s Work as members of a team in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results by

- communicating questions, ideas and intentions and receiving, interpreting, understanding, supporting and responding to the ideas of others during group work to collect data on gases **(CT–NS1)**
- using appropriate SI notation, fundamental and derived units and significant digits when performing calculations related to the gas laws **(CT–NS2)**; and, e.g., by
- *preparing a group presentation, using multimedia, to illustrate how pressure, temperature, volume and amount of a gas determines R, the universal gas constant* **(CT–ST2)** **[ICT P4–4.3]** **[ICT P4–4.1]**

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

Unit C: Matter as Solutions, Acids and Bases

Theme: Matter, Diversity, Systems and Change

Overview: Students gain an insight into the nature of matter through an investigation of change in the context of solutions, acids and bases.

This unit builds on:

- Science 8, Unit A: Mix & Flow of Matter
- Science 9, Unit B: Matter and Chemical Change
- Science 9, Unit C: Environmental Chemistry
- Science 10, Unit A: Energy and Matter in Chemical Change.

This unit provides students with a foundation for the study of Stoichiometry, Unit D in Chemistry 20, an introduction to Electrochemistry, Unit B, and Equilibrium, Unit D in Chemistry 30. This unit will require approximately 34% of the time allotment for Chemistry 20.

Links to Mathematics:

Topics:	These topics may be found in the following courses:
• rational equations that reduce to linear equations	Pure Mathematics 10, specific outcome 2.7; Applied Mathematics 10, specific outcomes 1.2, 1.3 and 5.1
• graphical and technological methods for solving non-linear (especially exponential) equations	Pure Mathematics 10, specific outcomes 3.1 and 4.2, and Pure Mathematics 20, specific outcomes 3.1 and 6.4; Applied Mathematics 10, specific outcomes 3.1, 3.2, 3.3 and 5.1, and Applied Mathematics 20, specific outcomes 2.1, 2.3, 2.4 and 2.5
• experimental results and experimental error	Applied Mathematics 20, specific outcomes 6.2, 6.3 and 6.4

Focusing Questions: How is matter as solutions, acids and bases differentiated on the basis of theories, properties and scientific evidence? Why is an understanding of acid/base and solution chemistry important in our daily lives and in the environment?

General Outcomes: There are two major outcomes in this unit.

Students will:

1. Investigate solutions, describing their physical and chemical properties and explaining the significance of concentration.
2. Describe acid and base systems qualitatively and quantitatively.

Key Concepts: The following concepts are developed in this unit and may also be addressed in other units at other levels. The intended level and scope of treatment is defined by the learning outcomes.

- homogeneous mixtures
- concentration
- dilution
- parts per million
- percent by mass
- hydronium ion
- hydroxide ion
- moles per litre
- electrolyte/non-electrolyte
- Workplace Hazardous Information Management System (WHMIS)

General Outcome 1: Investigate solutions, describing their physical and chemical properties and explaining the significance of concentration.

Outcomes for Knowledge

Students will:

20–C1.1k Provide examples from living and nonliving systems, showing how dissolving substances in water is often a prerequisite for chemical change

20–C1.2k Review the categories of pure substances and mixtures and explain the nature of homogeneous mixtures

20–C1.3k Differentiate between electrolytes and nonelectrolytes

20–C1.4k Describe dissolving as an endothermic or exothermic process

20–C1.5k Express concentration in various ways, i.e., moles per litre of solution, per cent by mass, parts per million

20–C1.6k Calculate, from empirical data, the concentration of solutions in moles per litre of solution and determine mass or volume from such concentrations

20–C1.7k Calculate the concentrations and/or volumes of diluted solutions and the quantities of a solution and water to use when diluting

20–C1.8k Use empirical data and dissociation equations to calculate the concentration of ions in a solution

20–C1.9k List and describe the steps required to prepare and dilute a solution

20–C1.10k Define solubility and the factors that affect it

20–C1.11k Explain a saturated solution in terms of an equilibrium system, i.e., equal rates of dissolving and crystallization

20–C1.12k Describe the procedures for safe handling, storing and disposal of solutions commonly used in the laboratory, with reference to WHMIS and consumer product labelling information

Outcomes for Science, Technology and Society (Emphasis on social and environmental contexts)

Students will:

20–C1.1sts Explain how science and technology are developed to meet societal needs and expand human capabilities (**STS1**), e.g.,

- *provide examples of how solutions and solution concentrations are applied in products and processes, in scientific studies, and in daily life*

20–C1.2sts Explain that science and technology are influenced and supported by society and have influenced, and been influenced by, historical development and societal needs (**STS2**), e.g.,

- *compare the ways in which concentrations of solutions are expressed in chemistry laboratories, household products and environmental studies*

20–C1.3sts Explain that scientific and technological activity may arise from, and give rise to, such personal and social values as accuracy, honesty, perseverance, tolerance, open-mindedness, critical-mindedness, creativity and curiosity (**STS5**), e.g.,

- *explain the Responsible Care® program developed by the Canadian Chemical Producers' Association*

20–C1.4sts Explain how science and technology have both intended and unintended consequences for humans and the environment (**STS3**), e.g.,

- *explain the significance of biomagnification in increasing the concentration of substances in the ecosystem*

20–C1.5sts Explain that the appropriateness, risks and benefits of technologies need to be assessed for each potential application from a variety of perspectives, including sustainability (**ST7**), e.g.,

- *explain the role of concentration in risk/benefit analysis for determining the safe limits of particular substances, e.g., pesticide residues, heavy metals, chlorinated or fluorinated compounds, pharmaceuticals*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 1: Investigate solutions, describing their physical and chemical properties and explaining the significance of concentration

Skill Outcomes (Focus on decision making)

Initiating and Planning

Students will:

20–C1.1s Ask questions about observed relationships and plan investigations of questions, ideas, problems and issues by

- designing a procedure for determining the concentration of a solution containing a solid solute (**IP–NS2**); and, e.g., by
- *designing a procedure to identify the type of solution* (**IP–NS2**) **[ICT C1–4.1]**

Performing and Recording

Students will:

20–C1.2s Conduct investigations into relationships among observable variables and use a broad range of tools and techniques to gather and record data and information by

- performing an experiment to determine the concentration of a solution (**PR–NS2, 5**) **[ICT C6–4.2]**
- using a conductivity apparatus to identify solutions (**PR–NS3**) **[ICT F1–4.2]**
- using a balance and volumetric glassware to prepare solutions of specified concentration (**PR–NS3, 5**) **[ICT F1–4.2]**
- performing an investigation to determine the solubility of a solute in a saturated solution (**PR–ST3, NS5**) **[ICT C6–4.2]**

Analyzing and Interpreting

Students will:

20–C1.3s Analyze data and apply mathematical and conceptual models to develop and assess possible solutions by

- collecting data and calculating solution concentrations in a titration experiment (**AI–NS2**) **[ICT C6–4.2]**
- performing an experiment to determine the concentration of a solution (**AI–NS3**) **[ICT C6–4.1]**; and, e.g., by
- *evaluating the risk involved in safe handling, storing and disposing of solutions in common use in the laboratory and in the home* (**AI–STS2, PR–NS5**)

Communication and Teamwork

Students will:

20–C1.4s Work as members of a team in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results by

- comparing personal concentration data with the data of other groups in a titration experiment (**CT–NS3**) **[ICT C2–4.2]**; and, e.g., by
- *selecting and using appropriate numeric, symbolic, graphical and linguistic modes of representation to communicate ideas, plans and results* (**CT–NS2**) **[ICT P2–4.1]**
- *using integrated software effectively and efficiently to incorporate data, graphics and text* **[ICT CT–ST2] [ICT P4–4.3]**
- *collectively researching the risk/benefit issue of pollution of waterways by the release of effluents and proposing a plan for reducing the impact on the ecosystem* (**PR–STS1, IP–STS3, AI–STS3**) **[ICT P3–4.1, C1–4.1]**

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 2: Describe acid and base systems qualitatively and quantitatively.

Outcomes for Knowledge

Students will:

- 20–C2.1k Review nomenclature of acids and bases
- 20–C2.2k Use indicators, pH and conductivity to differentiate among acidic, basic and neutral solutions
- 20–C2.3k Review the empirical definitions of acids and bases
- 20–C2.4k Describe the relationship between pH and hydronium ion concentration and pOH and hydroxide ion concentration
- 20–C2.5k Explain how the use of indicators, pH and conductivity can be used to differentiate pH and pOH
- 20–C2.6k Define acids, bases and neutralization, using the Brønsted-Lowry theory
- 20–C2.7k Identify conjugate pairs of Brønsted-Lowry acids and bases in chemical reaction equations
- 20–C2.8k Describe examples of substances that can act as either proton acceptors or proton donors (amphiprotic species)
- 20–C2.9k Compare magnitude changes in pH and pOH with changes in concentration
- 20–C2.10k Differentiate between the strength and concentration of strong and weak acids and strong and weak bases on the basis of empirical properties
- 20–C2.11k Calculate $H_3O^+_{(aq)}$ and $OH^-_{(aq)}$ concentrations, pH and pOH of solutions using the ionization constant for water K_w
- 20–C2.12k Use appropriate SI units to communicate the concentration and pH of solutions and express answers to the correct number of significant digits, i.e., use the number of decimal places in the pH to determine the number of significant digits of the concentration

Outcomes for Science, Technology and Society (Emphasis on science and technology)

Students will:

20–C2.1sts Explain that the goal of technology is to provide solutions to practical problems (**ST1**), e.g.,

- *relate the concept of pH to solutions encountered in everyday life, e.g., pharmaceuticals, shampoo and other cleaning products, aquatic and terrestrial environments, blood/blood products*

20–C2.2sts Explain that technological problems often have multiple solutions that involve different designs, materials and processes and have both intended and unintended consequences (**ST3**), e.g.,

- *provide examples of processes and products that use knowledge of acid and base chemistry, e.g., pulp and paper industry, food preparation/preservation, cleaning aids, sulfuric acid in car batteries, treating accidental acid or base spills using neutralization and dilution*
- *explain the significance of strength and concentration of solutions in everyday life, e.g., pharmaceuticals, chemical spills, transportation of dangerous goods, toxicity*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 2: Describe acid and base systems qualitatively and quantitatively.

Skill Outcomes (Focus on problem solving)

Initiating and Planning

Students will:

20–C2.1s Ask questions about observed relationships and plan investigations of questions, ideas, problems and issues by

- designing a procedure to determine the properties of acids and bases (**IP–NS2**) **[ICT C6–4.2]**
- designing an experiment to differentiate among acidic basic and neutral solutions (**IP–NS2**) **[ICT C6–4.3]**

Performing and Recording

Students will:

20–C2.2s Conduct investigations into relationships among observable variables and use a broad range of tools and techniques to gather and record data and information by

- constructing a table or graph to compare pH and hydronium ion concentration to illustrate that as the hydronium ion concentration increases, the pH decreases (**PR–NS4**) **[ICT P2–4.2]**; and, e.g., by
- *using a pH meter to determine acidity and/or alkalinity of a solution* (**PR–NS3**) **[ICT P2–4.1]**

Analyzing and Interpreting

Students will:

20–C2.3s Analyze data and apply mathematical and conceptual models to develop and assess possible solutions by

- comparing the pH of a variety of acids of the same concentration and inferring strength based on qualitative dissociation (**PR–NS2, AI–NS2, AI–NS6**) **[ICT C6–4.1]**; and, e.g., by
- *assessing, qualitatively, the risks and benefits of producing, using and transporting acidic and basic substances, based on WHMIS and Transportation of Dangerous Goods guidelines* (**AI–STS2**) **[ICT F3–4.1]**

Communication and Teamwork

Students will:

20–C2.4s Work as members of a team in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results, e.g., by

- *collectively researching the relation between sulphuric acid and industrialization* (**CT–STS1**) **[ICT C1–4.1]**
- *assessing technologies used to reduce emissions leading to acid deposition* (**CT–STS1, STS2**) **[ICT C6–4.4]**

Unit D: Quantitative Relationships in Chemical Changes

Themes: Matter and Change

Overview: Students focus on chemical change and the quantitative relationships contained in the balanced chemical equation. Students are required to use mathematical manipulation and stoichiometric principles to predict quantities of substances consumed or produced in chemical reaction systems.

This unit builds on:

- Science 10, Unit A: Energy and Matter in Chemical Change

This unit provides an introduction to Unit A: Thermochemistry, Unit B: Electrochemistry and Unit D: Equilibrium in Chemistry 30. This unit will require approximately 34% of the allotted time for Chemistry 20.

Links to Mathematics:

Topics:	These topics may be found in the following courses:
• rational equations that reduce to linear equations	Pure Mathematics 10, specific outcome 2.7; Applied Mathematics 10, specific outcomes 1.2, 1.3 and 5.1
• experimental results and experimental error	Applied Mathematics 20, specific outcomes 6.2, 6.3 and 6.4

Focusing Questions: How do scientists and engineers use mathematics to analyze chemical change? How are balanced chemical equations used to predict yields in chemical reactions?

General Outcomes: There are two major outcomes in this unit.

Students will:

1. Explain how balanced chemical equations indicate the quantitative relationships between reactants and products involved in chemical changes.
2. Use stoichiometry in quantitative analysis.

Key Concepts: The following concepts are developed in this unit and may also be addressed in other units at other levels. The intended level and scope of treatment is defined by the learning outcomes.

- chemical reaction equations
- net ionic equations
- spectator ions
- reaction stoichiometry
- precipitation
- limiting and excess species
- per cent yield

General Outcome 1: Explain how balanced chemical equations indicate the quantitative relationships among reactants and products involved in chemical changes.

Outcomes for Knowledge

Students will:

20–D1.1k Predict the product(s) of a chemical reaction based upon the reaction type

20–D1.2k Apply stoichiometry to analyze chemical equations in terms of atoms, molecules, ionic species and moles

20–D1.3k Differentiate between quantitative and qualitative analysis

20–D1.4k Identify spectator ions in reactions taking place in aqueous solutions

20–D1.5k Write balanced ionic and net ionic equations, including identification of spectator ions taking place in aqueous solutions

20–D1.6k Calculate the quantities of reactants and/or products involved in chemical reactions using gravimetric, solution or gas stoichiometry

Outcomes for Science, Technology and Society (Emphasis on science and technology)

Students will:

20–D1.1sts Explain that the focus in technology is on the development of solutions, involving devices and systems that meet a given need within the constraints of a problem (**ST2**), e.g.,

- *analyze the chemical reactions involved in various industrial and commercial processes and products that use stoichiometric and chemical principles, using examples from the following:*
  - *production of urea*
  - *fertilizers*
  - *fuel combustion*
  - *water treatment*
  - *air bag deployment*
  - *neutralization of excess stomach acid*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 1: Explain how balanced chemical equations indicate the quantitative relationships among reactants and products involved in chemical changes.

Skill Outcomes (Focus on problem solving)

Initiating and Planning

Students will:

20–D1.1s Ask questions about observed relationships and plan investigations of questions, ideas, problems and issues by

- planning and predicting states, products and theoretical yields for chemical reaction **(IP–NS3)** **[ICT C6–4.1]**
- designing an experiment to determine the process to identify an ion, e.g., precipitation, flame test **(IP–NS2)** **[ICT C6–4.2]**

Performing and Recording

Students will:

20–D1.2s Conduct investigations into relationships among observable variables and use a broad range of tools and techniques to gather and record data and information by

- translating word equations into skeleton equations, including states of matter for the products and reactants of a chemical reaction **(PR–NS4)** **[ICT C6–4.3]**
- balancing skeleton equations for chemical reactions, using lowest whole number coefficients **(PR–NS4)** **[ICT C6–4.3]**

Analyzing and Interpreting

Students will:

20–D1.3s Analyze data and apply mathematical and conceptual models to develop and assess possible solution by

- interpreting stoichiometric ratios from chemical reaction equations **(AI–NS2)** **[ICT C6–4.1]**
- performing calculations to determine theoretical yields **(AI–NS3)** **[ICT C6–4.1]**
- using appropriate SI notation, fundamental and derived units and significant digits when performing stoichiometry calculations **(AI–NS3, CT–ST2)** **[ICT P6–4.1]**

Communication and Teamwork

Students will:

20–D1.4s Work as members of a team in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results, e.g., by

- *using integrated software effectively and efficiently to incorporate data and text* **(AI–NS3, CT–ST2)** **[ICT P2–4.1]**

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 2: Use stoichiometry in quantitative analysis.

Outcomes for Knowledge

Students will:

20–D2.1k Explain quantitative analysis using chemical principles, i.e., conservation of mass in a chemical change

20–D2.2k Calculate the concentration of ions in solutions, using gravimetric procedures and evidence from reactions

20–D2.3k Identify limiting and excess species in chemical reactions

20–D2.4k Calculate theoretical yields and determine actual yields

20–D2.5k Explain the discrepancy between theoretical and actual yields

20–D2.6k Draw and interpret titration curve graphs, using data from titration experiments involving strong acids and strong bases

20–D2.7k Define and describe the function and choice of indicators in titrations

20–D2.8k Identify equivalence points on strong acid-base titration curves and differentiate between the indicator end point and the equivalence point

Outcomes for Science, Technology and Society (Emphasis on science and technology)

Students will:

20–D2.1sts Explain that scientific knowledge may lead to the development of new technologies and that new technologies may lead to scientific discovery (**ST4**), e.g.,

- *describe how industries apply principles of stoichiometry to minimize waste and maximize yield*

20–D2.2sts Explain how the appropriateness and the risks and benefits of technologies need to be assessed for each potential application from a variety of perspectives, including sustainability (**ST7**), e.g.,

- *assess the significance of specific by-products from industrial, commercial and household applications of chemical reactions*
- *analyze the use of technology to reduce environmental impact in SO_2 removal from smokestacks, catalytic converters in automobiles and reducing greenhouse gas emissions*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 2: Use stoichiometry in quantitative analysis.

Skill Outcomes (Focus on problem solving)

Initiating and Planning

Students will:

20–D2.1s Ask questions about observed relationships and plan investigations of questions, ideas, problems and issues by

- designing a method using crystallization, filtration or titration to determine the concentration of a solution (**IP–ST2**) [**ICT C6–4.1**]
- predicting the approximate equivalence for a titration and selecting an appropriate indicator (**IP–NS3,4**) [**ICT C6–4.2**]

Performing and Recording

Students will:

20–D2.2s Conduct investigations into relationships between and among observable variables and use a broad range of tools and techniques to gather and record data and information by

- performing a titration to determine the concentration of an acid or base (**PR–NS2**) [**ICT C6–4.2**] and, e.g., by
- *using probes and software to collect titration data* (**PR–NS3**) [**ICT P2–4.1**]
- *researching methods used by industry to reduce emissions* (**PR–ST1**) [**ICT F2–4.4**]
- *designing a prototype of a chemical industrial plant* (**PR–ST2**) [**ICT F2–4.1**]

Analyzing and Interpreting

Students will:

20–D2.3s Analyze data and apply mathematical and conceptual models to develop and assess possible solutions by

- evaluating an experiment based on a precipitation reaction, to determine the concentration of a solution (**PR–NS2,3,4,5; AI–NS3, 4, 6**) [**ICT C6–4.4**]
- creating titration curves for strong acid-strong base experiments (**PR–NS4**) [**ICT C7–4.1**]
- calculating percent yield and explaining the discrepancies between the theoretical and actual yields (**AI-NS3, 4**) (**PR–NS2,3,4,5**) [**ICT C6–4.3**]
- using appropriate SI notation, fundamental and derived units and significant digits when performing stoichiometry calculations (**AI–NS3, CT–ST2**) [**ICT P6–4.1, F1–4.3**]

Communication and Teamwork

Students will:

20–D2.4s Work as members of a team in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results by

- standardizing an acid or base solution and comparing group results (**PR–NS2**) [**ICT C2–4.2**]; and, e.g., by
- *drawing a flowchart for an industrial chemical process* (**CT–ST2**) [**ICT C6–4.4**]
- *using integrated software effectively and efficiently to produce work that incorporates data, graphics and text* (**CT–ST2**) [**ICT P4–4.3**]

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

CHEMISTRY 30

Chemistry 30 consists of four units of study:
A. Thermochemical Changes
B. Electrochemical Changes
C. Chemical Changes of Organic Compounds
D. Equilibrium in Chemical Changes

Attitude Outcomes for Chemistry 30

Students will be encouraged to develop positive attitudes that support the responsible acquisition and application of knowledge related to science and technology. The following attitude outcomes are to be developed throughout the Chemistry 30 program, in conjunction with the outcomes for Knowledge, Science, Technology and Society (STS) and Skills in each unit.

Interest in Science

Students will be encouraged to:
Show interest in science-related questions and issues and confidently pursue personal interest and career possibilities within science-related fields, e.g.,
- *appreciate how scientific problem solving and the development of new technologies are related*
- *recognize the contributions of science and technology to the progress of civilizations*
- *demonstrate interest in science and technology topics related to everyday life*
- *recognize the usefulness of being skilled at mathematics and problem solving*
- *explore how further science- and technology-related studies can be pursued*
- *investigate careers in the fields of research and industry*

Mutual Respect

Students will be encouraged to:
Appreciate that scientific understanding evolves from the interaction of ideas involving people with different views and backgrounds, e.g.,
- *develop an interest in global energy issues and the effectiveness of local activities in contributing to the solution of problems related to energy*
- *recognize the contributions of various peoples and cultures in advancing understanding and applications of chemistry*

Scientific Inquiry

Students will be encouraged to:
Seek and apply evidence when evaluating alternative approaches to investigations, problems and issues, e.g.,
- *value the need for accuracy and precision in data collection*
- *appreciate the creativity and perseverance required to develop workable solutions to problems*
- *tolerate the uncertainty involved in experimentation*
- *appreciate that the knowledge of chemistry has been enhanced by the evidence obtained from the application of technology, particularly instruments for making measurements and managing data*
- *research alternative models, explanations and theories when confronted with discrepant events*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

- *critically evaluate inferences and conclusions and recognize bias, being aware of the many variables involved in experimentation*
- *appreciate the importance of careful laboratory techniques and precise calculations in obtaining accurate results*

Collaboration

Students will be encouraged to:
Work collaboratively in planning and carrying out investigations, and in generating and evaluating ideas, e.g.
- *assume a variety of roles within a group, as required*
- *accept responsibility for any task that helps the group complete an activity*
- *evaluate the ideas of others objectively*

Stewardship

Students will be encouraged to:
Demonstrate sensitivity and responsibility in pursuing a balance between the needs of humans and a sustainable environment, e.g.,
- *consider all perspectives when addressing issues related to energy use, weighing scientific, technological and ecological factors*
- *develop a sense of responsibility toward the use of energy*
- *develop a sense of responsibility regarding the use and disposal of chemicals and materials*
- *identify and evaluate ways of using chemical potential energy sources more efficiently*
- *develop an awareness that the application of technology has risks and benefits*
- *evaluate the contributions of technological innovations to the quality of life*
- *evaluate the choices that scientists and technologists make when carrying out controversial research*

Safety

Students will be encouraged to:
Show concern for safety in planning, carrying out and reviewing activities, e.g.,
- *include safety as a requirement in scientific and technological endeavours*
- *keep the workstation uncluttered, with only appropriate laboratory materials present*
- *use equipment and materials appropriately*
- *assume responsibility for the safety of all those who share a common working environment*
- *clean up after an activity and dispose of materials in a safe place*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

Unit A: Thermochemical Changes

Themes: Energy, Change and Systems

Overview: In this unit, students study energy as it relates to chemical changes and quantify the energy involved in thermochemical systems.

This unit builds on:

- Science 9, Unit C: Heat Energy: Transfer and Conservation
- Science 10, Unit A: Energy and Matter in Chemical Change
- Science 10, Unit D: Energy Flow in Global Systems

This unit prepares students for introductory chemistry courses at the post-secondary level. This unit will require approximately 23% of the time allotted for Chemistry 30.

Links to Mathematics:

Topics:	These topics may be found in the following courses:
• rational equations that reduce to linear equations	Pure Mathematics 10, specific outcome 2.7; Applied Mathematics 10, specific outcomes 1.2, 1.3 and 5.1
• experimental results and experimental error	Applied Mathematics 20, specific outcomes 6.2, 6.3 and 6.4

Focusing Questions: How does our society use the energy of chemical changes? How do chemists determine how much energy will be produced or absorbed for a given chemical reaction?

General Outcomes: There are two major outcomes in this unit.

Students will:

1. Determine energy changes in chemical reactions.
2. Explain chemical changes using energy diagrams.

Key Concepts: The following concepts are developed in this unit and may also be addressed in other units at other levels. The intended level and scope of treatment is defined by the learning outcomes.

- molar enthalpy
- ΔH notation
- heat of reaction
- activation energy
- fuels and energy efficiency
- Hess' law
- energy diagrams
- catalysts
- heat of formation

General Outcome 1: Determine energy changes in chemical reactions.

Outcomes for Knowledge

Students will:

30–A1.1k	Explain, in a general way, how stored energy in the chemical bonds of hydrocarbons originated from the Sun
30–A1.2k	Write balanced equations for chemical reactions that include energy changes
30–A1.3k	Use and interpret change in enthalpy (ΔH) notation for communicating energy changes
30–A1.4k	Define molar enthalpy/change for the heats of chemical changes
30–A1.5k	Predict the heat of reaction for chemical changes using standard heats of formation
30–A1.6k	Define and use Hess' law to calculate energy changes in chemical reactions
30–A1.7k	Use calorimetry to determine the enthalpy changes in chemical reactions
30–A1.8k	Recognize that water and carbon dioxide are reactants for photosynthesis and products for respiration and combustion
30–A1.9k	Classify, qualitatively, the processes of photosynthesis, cellular respiration and hydrocarbon combustion as endothermic or exothermic

Outcomes for Science, Technology and Society (Emphasis on science and technology)

Students will:

30–A1.1sts Explain that the goal of technology is to provide solutions to practical problems (**ST1**), e.g.,

- *provide examples of personal reliance on the chemical potential energy of matter, e.g., the use of hydrocarbon fossil fuels*

30–A1.2sts Demonstrate an understanding that technological problems often lend themselves to multiple solutions that involve different designs, materials and processes and have intended and unintended consequences (**ST3**), e.g.,

- *illustrate the importance of hydrocarbon fossil fuels, with examples from industries in Alberta*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 1: Determine energy changes in chemical reactions.

Skill Outcomes (Focus on problem solving)

Initiating and Planning

Students will:

30–A1.1s Ask questions about observed relationships and plan investigations of questions, ideas, problems and issues by

- designing a method to compare the molar enthalpy change when burning two or more fuels, identifying and controlling major variables (**IP–ST1, 2**) **[ICT C1–4.2]**

Performing and Recording

Students will:

30–A1.2s Conduct investigations into relationships among observable variables and use a broad range of tools and techniques to gather and record data and information by

- performing calorimetry experiments to determine the molar enthalpy change of chemical reactions (**PR–NS2**) **[ICT C6–4.2]**
- using thermometers or temperature probes appropriately when measuring temperature changes (**PR–NS3/PR–ST3**) **[ICT F3–4.2]**; and, e.g., by
- *using a computer-based laboratory to compile and organize data from an experiment to demonstrate molar enthalpy change* (**PR–NS4**) **[ICT F1–4.2]**
- *selecting and integrating information from various print and electronic sources to create multiple-linked documents on using alternative fuels* (**PR–ST1**) **[ICT P4–4.3]**

Analyzing and Interpreting

Students will:

30–A1.3s Analyze data and apply mathematical and conceptual models to develop and assess possible solutions by

- comparing energy changes associated with chemical reactions (**AI–NS3**) **[ICT C6–4.2]**; and, e.g., by
- *manipulating and presenting data through the selection of appropriate tools, e.g., scientific instrumentation, calculators, databases or spreadsheets* (**AI–ST3**) **[ICT P2–4.1]**

Communication and Teamwork

Students will:

30–A1.4s Work as members of a team in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results by

- using appropriate SI notation, fundamental and derived units for enthalpy changes and expressing molar enthalpies in kilojoules/mole (**CT–NS2**) **[ICT F1–4.3]**; and, e.g., by
- *using advanced menu features within a word processor to accomplish a task and to insert tables, graphs, text and graphics* (**CT–STS2**) **[ICT P4–4.3]**

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 2: Explain and communicate energy changes in chemical reactions.

Outcomes for Knowledge

Students will:

30–A2.1k Analyze and label energy diagrams for a chemical reaction, including reactants, products, enthalpy change and activation energy, using graphing conventions

30–A2.2k Explain the energy changes that occur during chemical reactions based on chemical bonds breaking and forming

30–A2.3k Explain that catalysts provide alternative pathways for chemical changes without affecting the net amount of energy produced or absorbed in chemical and biochemical processes, e.g., *enzymes in living systems*

Outcomes for Science, Technology and Society (Emphasis on Science and Technology)

Students will:

30–A2.1sts Develop an understanding that the goal of technology is to provide solutions to practical problems (**ST1**), e.g.,

- *explain how catalysts reduce air pollution from the burning of hydrocarbons*

30–A2.2sts Identify the appropriateness, risks and benefits of technologies and the need to assess each potential application from a variety of perspectives, including sustainability (**ST7**), e.g.,

- *assess qualitatively the risks and benefits of relying on fossil fuels as energy sources*

30–A2.3sts Explain that the products of technology are devices, systems and processes that meet given needs but that these products cannot solve all problems (**ST6**), e.g.,

- *evaluate the economic and environmental impact of different fuels by relating carbon dioxide emissions and the heat content of a fuel*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 2: Explain and communicate energy changes in chemical reactions.

Skill Outcomes (Focus on problem solving)

Initiating and Planning

Students will:

30–A2.1s Ask questions about observed relationships and plan investigations of questions, ideas, problems and issues by

- selecting a method to compare the molar enthalpy change when burning two or more fuels, identifying and controlling major variables (**IP–ST2**) [**ICT C1–4.2**]

Performing and Recording

Students will:

30–A2.2s Conduct investigations into relationships among observable variables and use a broad range of tools and techniques to gather and record data and information by

- plotting energy graphs/enthalpy diagrams (**PR–NS4**) [**ICT P3–4.3**]; and, e.g., by
- *using library and electronic research tools to compile information on the energy content of fuels used in Alberta power plants* (**PR–ST1**) [**ICT C1–4.1**]
- *designing and building a heating device* (**PR–ST2**) [**ICT F2–4.1**]

Analyzing and Interpreting

Students will:

30–A2.3s Analyze data and apply mathematical and conceptual models to develop and assess possible solutions by

- interpreting a change in an enthalpy diagram (**AI–NS2**) [**ICT C6–4.3**]
- explaining the discrepancy between the theoretical and actual efficiency of a thermal energy conversion system (**AI–NS3**) [**ICT F2–4.5**]; and, e.g., by
- *determining the efficiency of thermal energy conversion systems* (**AI–NS3**) [**ICT C6–4.4**]
- *assessing whether coal or natural gas should be used to fuel thermal power plants in Alberta* (**AI–ST2**) [**ICT C1–4.1**]
- *evaluating a personally designed and constructed heating device, including a calculation of its efficiency* (**AI–ST2**) [**ICT C6–4.5**]

Communication and Teamwork

Students will:

30–A2.4s Work as members of a team in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results by

- using appropriate SI notation, fundamental and derived units for enthalpy changes (**CT–ST2**) [**ICT F1–4.3**]; and, e.g., by
- *working cooperatively with team members to develop a plan to build an energy conversion device, seeking feedback, testing and reviewing the plan, making revisions and implementing the plan* (**CT–ST1**) [**ICT P6–4.1**]
- *using advanced menu features within a word processor to accomplish a task and to insert tables, graphs, text and graphics* (**CT–STS2**) [**ICT P4–4.3**]

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

Unit B: Electrochemical Changes

Themes: Change and Energy

Overview: In this unit, students study electrochemical change and analyze the matter and energy changes within a system.

This unit builds on:

- Science 9, Unit D: Electrical Principles and Technologies
- Science 10, Unit A: Energy and Matter in Chemical Change
- Chemistry 20, Unit B: Chemical Bonding
- Chemistry 20, Unit D: Quantitative Relationships in Chemical Changes

This unit prepares students for post-secondary studies in related areas. This unit will require approximately 31% of the time allotted for Chemistry 30.

Links to Mathematics:

Topics:	These topics may be found in the following courses:
• rational equations that reduce to linear equations	Pure Mathematics 10, specific outcome 2.7; Applied Mathematics 10, specific outcomes 1.2, 1.3 and 5.1
• experimental results and experimental error	Applied Mathematics 20, specific outcomes 6.2, 6.3 and 6.4

Focusing Questions: What is an electrochemical change? How have scientific knowledge and technological innovation been integrated in the field of electrochemistry?

General Outcomes: There are two major outcomes developed in this unit.

Students will:

1. Explain the nature of oxidation-reduction reactions.
2. Apply the principles of oxidation-reduction to electrochemical cells.

Key Concepts: The following concepts are developed in this unit and may also be addressed in other units at other levels. The intended level and scope of treatment is defined by the learning outcomes.

- oxidation
- reduction
- oxidizing agent
- reducing agent
- oxidation number
- half reaction
- disproportionation
- spontaneity
- standard reduction potential
- Voltaic cell
- electrolyis
- electrolytic cell
- standard net cell potential
- batteries
- fuel cells
- Faraday's law
- corrosion

General Outcome 1: Explain the nature of oxidation-reduction reactions.

Outcomes for Knowledge

Students will:

30–B1.1k Formulate operational definitions for major variables, including oxidation and reduction

30–B1.2k Define oxidation as a loss of electrons and reduction as a gain of electrons

30–B1.3k Define the following terms: oxidizing agent, reducing agent, oxidation number, half-reaction, disproportionation

30–B1.4k Differentiate between oxidation-reduction reactions and other reactions that do not involve oxidation-reduction by identifying half-reactions and changes in oxidation number

30–B1.5k Identify electron transfer, oxidizing agents and reducing agents in oxidation-reduction reactions

30–B1.6k Compare the relative strengths of oxidizing and reducing agents from empirical data

30–B1.7k Predict the spontaneity of a redox reaction experimentally and theoretically

30–B1.8k Write and balance equations for oxidation-reduction reactions in acidic, basic and neutral solutions, including disproportionation reactions, by

- using half-reaction equations obtained from a standard reduction potential table
- developing simple half-reaction equations from information provided about oxidation-reduction changes
- assigning oxidation numbers or average oxidation numbers, where appropriate, to the species undergoing chemical change

30–B1.9k Perform calculations to determine quantities of substances involved in oxidation-reduction titrations

Outcomes for Science, Technology and Society (Emphasis on science and technology)

Students will:

30–B1.1sts Explain how the goal of technology is to provide solutions to practical problems (**ST1**), e.g.,

- *identify oxidation-reduction reactions that occur in everyday life in both living and non-living systems, e.g., corrosion, metallurgy, cellular respiration, photosynthesis*

30–B1.2sts Explain that technological problems often lend themselves to multiple solutions that involve different designs, materials and processes and have intended and unintended consequences (**ST3**), e.g.,

- *analyze oxidation-reduction reactions used in industry and commerce, e.g., pulp and paper, textiles, water treatment, food processing*

30–B1.3sts Describe applications of science and technology that have developed in response to human and environmental needs (**ST6**), e.g.,

- *investigate the use of technology to solve practical problems related to corrosion*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 1: Explain the nature of oxidation-reduction reactions.

Skill Outcomes (Focus on problem solving)

Initiating and Planning

Students will:

30–B1.1s Ask questions about observed relationships and plan investigations of questions, ideas, problems and issues by

- designing an experiment to determine the reactivity of various metals (**IP–NS1, 2, 3**) [**ICT C6–4.5**]

Performing and Recording

Students will:

30–B1.2s Conduct investigations into relationships among observable variables and use a broad range of tools and techniques to gather and record data and information by

- selecting and correctly using the appropriate equipment to perform an oxidation-reduction titration experiment (**PR–NS2,3**) [**ICT P2–4.1**]
- using a standard reduction potential table as a tool in predicting the spontaneity of oxidation-reduction reactions and their products (**PR–ST3**) [**ICT C6–4.1**]; and, e.g., by
- *creating charts, tables or spreadsheets which present the results of oxidation-reduction experiments* (**PR–NS4**) [**ICT C7–4.2**]

Analyzing and Interpreting

Students will:

30–B1.3s Analyze data and apply mathematical and conceptual models to develop and assess possible solutions by

- evaluating data from an experiment to derive a simple reduction table (**AI–ST3, NS4**) [**ICT C6–4.5**]; and, e.g., by
- *interpreting patterns and trends in data derived from oxidation-reduction reactions* (**A1–NS2**)[**ICT C6–4.5**]
- *identifying the limitations of data collected* (**A1–NS4**) [**ICT P3–4.3**]

Communication and Teamwork

Students will:

30–B1.4s Work as members of a team in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results by

- selecting and using appropriate numeric, symbolic, graphic and linguistic modes of representation to communicate equations for oxidation-reduction reactions (**CT–ST2**) [**ICT P3–4.3**]

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 2: Apply the principles of oxidation-reduction to electrochemical cells.

Outcomes for Knowledge

Students will:

30–B2.1k Define anode, cathode, anion, cation, salt bridge/porous cup, external circuit, power supply, voltaic cell and electrolytic cell

30–B2.2k Identify the similarities and differences between the operation of a voltaic cell and that of an electrolytic cell

30–B2.3k Predict and write the half-reaction equation that occurs at each electrode

30–B2.4k Recognize that predicted reactions do not always occur, i.e., the production of chlorine gas from the electrolysis of brine

30–B2.5k Explain that the values of standard reduction potential are all relative to E°=0.00V set for the hydrogen electrode at standard conditions

30–B2.6k Calculate standard cell potential values for electrochemical cells

30–B2.7k Predict the spontaneity or non-spontaneity of oxidation-reduction reactions on the basis of calculated standard cell potential values and the relative positions of half-reaction equations on a standard reduction potential table

30–B2.8k Calculate the quantities of mass, volume, concentration, current and time in single Voltaic and electrolytic cells by applying Faraday's law to solve stoichiometric problems

Outcomes for Science, Technology and Society (Emphasis on science and technology)

Students will:

30–B2.1sts Describe the ways in which scientific knowledge may lead to the development of new technologies and new technologies may lead to scientific discoveries (**ST4**), e.g.,

- *analyze the relationship of scientific knowledge and technological development in the applications of Voltaic and electrolytic cells for, e.g., batteries, electroplating, refining metals from ores, sanitizing swimming pools*

30–B2.2sts Illustrate how science and technology are influenced and supported by society and have influenced and been influenced by historical development and societal needs (**STS2**), e.g.,

- *assess the economic importance of Voltaic and electrochemical cells, particularly fuel cells, to modern society, predicting their future importance in transportation, the recycling of metals and in reducing emissions from smokestacks*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 2: Apply the principles of oxidation-reduction to electrochemical cells.

Skill Outcomes (Focus on problem solving)

Initiating and Planning

Students will:

30–B2.1s Ask questions about observed relationships and plan investigations of questions, ideas, problems and issues by

- designing an experiment, including a labelled diagram, to test predictions about oxidation-reduction reactions with regard to spontaneity, products and standard cell potential values and identifying and controlling major variables (**IP–NS1,2,3**) [**ICT C6–4.1**]; and, e.g., by
- *developing a plan to build a battery, seeking feedback, testing and reviewing the plan, and making revisions to the plan* (**IP–ST2**) [**ICT C6–4.5**]

Performing and Recording

Students will:

30–B2.2s Conduct investigations into relationships between and among observable variables and use a broad range of tools and techniques to gather and record data and information by

- constructing, observing and identifying products for Voltaic cells (**PR–ST2, 3; PR–NS5**) [**ICT C6–4.4**]; and, e.g., by
- *investigating the issue of the disposal of used batteries and proposing alternative solutions to this problem* (**PR–ST1, AI–ST2**) [**ICT CT–4.2**]
- *compiling and displaying evidence and information about Voltaic and electrochemical cells, by hand or using technology, in a variety of formats, including diagrams, flow charts, tables, graphs and scatterplots* (**PR–NS4**) [**ICT P2–4.1**]

Analyzing and Interpreting

Students will:

30–B2.3s Analyze data and apply mathematical and conceptual models to develop and assess possible solutions by

- identifying the products produced by an electrolytic cell (**AI–NS3**) [**ICT C6–4.2**]
- comparing predictions and observations (**AI–ST1, 2**) [**ICT C7–4.2**]; and, e.g., by
- *identifying the limitations of data collected on a electrochemical cell* (**AI–NS4**) [**ICT C7–4.2**]
- *explaining the discrepancies between theoretical and actual cell potential values* (**AI–NS4**) [**ICT C6–4.4**]
- *assessing the efficiencies and practicalities of various electrochemical configurations as batteries* (**AI–ST2**) [**ICT C2–4.1**]
- *evaluating experimental designs for Voltaic and electrolytic cells, identifying limitations and suggesting improvements and alternatives* (**AI–ST1**) [**ICT C2–4.2**]

Communication and Teamwork

Students will:

30–B2.4s Work as members of a team in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results by

- using appropriate SI notation, fundamental and derived units to communicate answers to problems (**CT–ST2**) [**ICT F1–4.3**]; and, e.g., by
- *creating multiple-linked documents, selecting and integrating information from various print and electronic sources or from several parts of the same source, to prepare a presentation on the use of hydrogen fuel cells for transportation and heating* (**CT–STS2**) [**ICT P4–4.1**]

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

Unit C: Chemical Changes of Organic Compounds

Themes: Change, Diversity and Energy

Overview: Students learn about common organic compounds and describe their properties and reactions. The significance of organic chemistry in the context of technological applications and quality of life is explored.

This unit builds on:
- Chemistry 20, Unit A: Bonding

Links to Mathematics: None

This unit prepares students for post-secondary studies in related areas. This unit will require approximately 23% of the time allotted to Chemistry 30.

Focusing Questions: What are the common organic compounds and what is the system for naming them? How does society exploit the reactions of organic compounds? How can society ensure that the technical applications of organic chemistry are assessed to ensure future quality of life and a sustainable environment?

General Outcomes: There are two major outcomes in this unit.

Students will:
1. Explore organic compounds as a common form of matter.
2. Describe the chemical reactions of organic compounds.

Key Concepts: The following concepts are developed in this unit and may also be addressed in other units at other levels. The intended level and scope of treatment is defined by the learning outcomes.
- organic compounds
- naming conventions
- structural formulas
- structural isomers
- functional groups including: hydrocarbons, halogenated hydrocarbons, aromatics, aliphatics, alcohols, aldehydes, ketones, carboxylic acid, amines, amides, esters and ethers
- esterification
- combustion reactions
- monomers, polymers
- polymerization
- addition, substitution
- elimination

General Outcome 1: Explore organic compounds as a common form of matter.

Outcomes for Knowledge

Students will:

30–C1.1k Define organic compounds in terms of the presence of carbon and type of bonding

30–C1.2k Name and draw formulas with up to 10 carbon atoms, using International Union of Pure and Applied Chemistry (IUPAC), i.e.,
- aliphatic (including cyclical) and aromatic hydrocarbons
- organic compounds containing a single functional group

30–C1.3k Define structural isomerism, using examples

30–C1.4k Compare the relative boiling points and solubility of aliphatics, aromatics, alcohols, ketones, carboxylic acids and ethers

30–C1.5k Gather data to compare the properties of a pair of organic isomers

30–C1.6k Identify types of compound from the functional groups, given the structural formula

30–C1.7k Describe, in general terms, processes by which organic compounds are separated from natural mixtures or solutions, e.g., *fractional distillation, bitumen recovery*

Outcomes for Science, Technology and Society (Emphasis on social and environmental contexts)

Students will:

30–C1.1sts Demonstrate an understanding that science and technology are developed to meet societal needs and expand human capability (**STS1**), e.g.,
- *identify organic compounds and their significance to daily life*
- *describe examples of organic compounds, their origins and their applications, e.g., where they are found, how they are used in processes and common products*

30–C1.2sts Explain how science and technology are influenced and supported by society and have influenced, and been influenced by, historical development and societal needs (**STS2**), e.g.,
- *explain how, as a result of chemistry and chemical technology, synthetic compounds of great benefit to society have been produced, e.g. insulin, nylon and pesticides*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 1: Explore organic compounds as a common form of matter.

Skill Outcomes (Focus on decision making)

Initiating and Planning

Students will:

30–C1.1s Ask questions about observed relationships and plan investigations of questions, ideas, problems and issues by

- designing a procedure to identify types of organic compounds (**IP–NS1**) **[ICT C1–4.1]**; and, e.g., by
- *designing a procedure for separating a mixture of organic compounds based on boiling point differences* (**IP–ST2, 3**) **[ICT C6–4.4]**

Performing and Recording

Students will:

30–C1.2s Conduct investigations into relationships between and among observable variables and use a broad range of tools and techniques to gather and record data and information by

- building molecular models depicting the structures of selected organic compounds (**PR–NS4**) **[ICT C6–4.4]**
- performing an experiment to investigate the properties of organic compounds (**IP–NS2, PR–NS2,3,5**) **[ICT C6–4.1]**
- testing for the presence of a single bond versus a double or triple bond in aliphatics (**PR–NS3**) **[ICT C6–4.2]**

Analyzing and Interpreting

Students will:

30–C1.3s Analyze data and apply mathematical and conceptual models to develop and assess possible solutions by

- following appropriate IUPAC guidelines in writing the names and formulas of organic compounds (**AI–NS1**) **[ICT C7–4.2]**
- compiling and organizing data to compare the properties of organic isomers (**AI–NS1**) **[ICT C6–4.2]**; and, e.g., by
- *analyzing the contributions and limitations of scientific and technological knowledge to societal decision making in relation to the costs and benefits of society's use of petrochemicals pharmaceuticals and pesticides* (**AI–STS2**) **[ICT F3–4.1]**

Communication and Teamwork

Students will:

30–C1.4s Work as members of a team in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results, e.g., by

- *using advanced menu features within a word processor to accomplish a task and to insert tables, graphs, text and graphics* (**CT–STS2**) **[ICT P3–4.3]**

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 2: Describe the chemical reactions of organic compounds.

Outcomes for Knowledge

Students will:

30–C2.1k Define, predict products of and provide examples of addition, substitution, elimination, esterification and combustion reactions

30–C2.2k Write balanced equations for chemical reactions involving organic compounds

30–C2.3k Define, with reference to examples and basic structure, monomers, polymers (addition and condensation) and polymerization in living and nonliving systems, e.g., *proteins, carbohydrates, textiles, plastics*

Outcomes for Science, Technology and Society (Emphasis on social and environmental contexts)

Students will:

30–C2.1sts Develop an understanding that science and technology are developed to meet societal needs and expand human capability (**STS1**), e.g.,

- *describe major reactions of the petrochemical industry in Alberta, e.g., production of methanol, ethylene glycol, polyethylene, polyvinyl chloride (PVC), urea, formaldehyde*
- *describe processes for obtaining economically important compounds from petroleum and bitumen, e.g.,*
  - *compare hydro-cracking and reforming*
  - *describe bitumen upgrading*

30–C2.2sts Develop an understanding that science and technology are influenced and supported by society and have influenced, and been influenced by, historical development and societal needs (**STS2**), e.g.,

- *describe processes involved in producing gasoline, e.g.,*
  - *adjusting octane rating*
  - *reducing sulfur content*
  - *adding compounds such as oxygenated additives (blending with ethanol)*

30–C2.3sts Develop an understanding that science and technology have both intended and unintended consequences for humans and the environment (**STS3**), e.g.,

- *assess the positive and negative effects of various reactions involving organic compounds, relating these processes to quality of life and potential environmental problems, e.g.,*
  - *production of pharmaceuticals*
  - *byproducts (CO_2, dioxins) of common reactions*
  - *recycling of plastics*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 2: Describe the chemical reactions of organic compounds.

Skill Outcomes (Focus on decision making)

Initiating and Planning

Students will:

30–C2.1s Ask questions about observed relationships and plan investigations of questions, ideas, problems and issues by

- predicting the ester formed from an alcohol and an organic acid (**IP–NS2**) [**ICT C1–4.2**]; and, e.g., by
- *designing a procedure to prepare a polymer* (**IP–NS1**) [**ICT C1–4.2**]

Performing and Recording

Students will:

30–C2.2s Conduct investigations into relationships between and among observable variables and use a broad range of tools and techniques to gather and record data and information by

- performing an experiment to investigate the reactions of organic compounds (**IP–NS 1,2,3,4**) [**ICT C7–4.2**]; and, e.g., by
  - *synthesizing a polymer, e.g., nylon or "slime"*
  - *producing an ester*
  - *investigating methods of making soap*
- *using library and electronic research tools to collect information on, e.g.,* (**PR–STS1, 2**) [**ICT P3–4.1**]
  - *bitumen upgrading*
  - *determining the octane ratings of gasoline*
  - *the costs and benefits of supporting the petrochemical industry*

Analyzing and Interpreting

Students will:

30–C2.3s Analyze data and apply mathematical and conceptual models to develop and assess possible solutions by

- using appropriate chemical symbols and nomenclature in writing organic chemical reactions (**AI–NS1**) [**ICT F1–4.3**]
- investigating the issue of greenhouse gases, i.e., methane, carbon dioxide, water and nitrogen oxides and the potential for climate change (**AI–STS 1,2**) [**ICT F3–4.1**]; and, e.g., by
- *analyzing a process for producing polymers* (**AI–ST1**) [**ICT C7–4.2**]
- *analyzing efficiencies and negative byproducts related to chemical reaction processes in organic chemistry* (**AI–ST2**) [**ICT F3–4.1**]

Communication and Teamwork

Students will:

30–C2.4s Work as members of a team in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results, e.g., by

- *using advanced menu features within a word processor to insert tables, graphs, text and graphics when preparing a report on an issue related to society's use of organic chemistry* (**CT–STS2**) [**ICT P4–4.3**]

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

Unit D: Equilibrium in Chemical Changes

Themes: Change, Systems and Equilibrium

Overview: In this unit, the concept that change eventually attains equilibrium is expanded to a quantitative treatment of reaction systems involving ideal gases and solutions. Students are introduced to buffer systems.

This unit builds on:

- Science 8, Unit 1: Solutions and Substances
- Science 9, Unit B: Matter and Chemical Change
- Science 10, Unit A: Energy and Matter in Chemical Change
- Chemistry 20, Unit A: Matter as Solutions, Acids, Bases, and Unit D: Quantitative Relationships in Chemical Changes

This unit prepares students for post-secondary studies in related areas. This unit will require approximately 23% of the time allotted for Chemistry 30.

Links to Mathematics:

Topics:	These topics may be found in the following courses:
• rational equations that reduce to linear equations	Pure Mathematics 10, specific outcome 2.7; Applied Mathematics 10, specific outcomes 1.2, 1.3 and 5.1
• plotting non-linear data	Pure Mathematics 10, specific outcome 3.1; Applied Mathematics 10, specific outcome 3.1
• graphical or algebraic methods to solve non-linear (especially quadratic) equations	Pure Mathematics 10, specific outcome 4.2, and Pure Mathematics 20, specific outcomes 2.1, 2.3, 2.4, and 3.1
• experimental results and experimental error	Applied Mathematics 20, specific outcomes 6.2, 6.3 and 6.4

Focusing Questions: What is happening in a system at equilibrium? How do scientists predict shifts in the equilibrium of a system? How do buffers maintain pH?

General Outcomes: There are two major outcomes in this unit.

Students will:

1. Explain that there is a balance of opposing reactions in chemical equilibrium systems.
2. Determine quantitative relationships in chemical equilibrium systems.

Key Concepts: The following concepts are developed in this unit and may also be addressed in other units at other grade levels. The intended level and scope of treatment is defined by the learning outcomes.

- equilibrium systems
- reversibility
- equilibrium law expression
- equilibrium constant
- Le Chatelier's principle
- acid-base equilibria
- buffers

General Outcome 1: Explain that there is a balance of opposing reactions in chemical equilibrium systems.

Outcomes for Knowledge

Students will:

30–D1.1k Define equilibrium and state the criteria that apply to a system in equilibrium, i.e., closed system, constancy of properties, equal rates of forward and reverse reactions

30–D1.2k Write and interpret chemical equations for systems at equilibrium

30–D1.3k Write equilibrium expressions for all equations, using lowest whole number coefficients

30–D1.4k Predict, qualitatively, shifts in equilibrium caused by changes in temperature, pressure, volume or concentration, using Le Chatelier's principle, and whether these changes affect the equilibrium constant

30–D1.5k Explain that catalysts do not affect concentrations at equilibrium, only the time it takes to reach equilibrium

30–D1.6k Formulate an operational and theoretical definition of a buffer

30–D1.7k Explain how an indicator is a system in equilibrium

Outcomes for Science, Technology and Society (Emphasis on Nature of Science)

Students will:

30–D1.1sts Demonstrate an understanding that the goal of science is knowledge about the natural world (**NS1**), e.g.,

- *apply equilibrium theories and principles to analyze a variety of phenomena, e.g.,*
  - *buffers found in living systems*
  - *carbon dioxide escaping from an open bottle of soda pop*
  - *precipitation of limestone in caves*
  - *rapid corrosion of metals in the presence of an acid*
  - *role of the oceans in the carbon cycle*

30–D1.2sts Demonstrate an understanding that scientific knowledge and theories develop through hypotheses, the collection of evidence through experimentation and the ability to provide explanations (**NS2**), e.g., research how equilibrium theories and principles developed

30–D1.3sts Demonstrate an understanding that the goal of technology is to provide solutions to practical problems (**ST1**), e.g.,

- *analyze how equilibrium principles have been applied in industrial processes, e.g.,*
  - *the Haber-Bosch process for making ammonia*
  - *the Solvay process for making sodium carbonate*
  - *production of methanol*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 1: Explain that there is a balance of opposing reactions in chemical equilibrium systems.

Skill Outcomes (Focus on scientific inquiry)

Initiating and Planning

Students will:

30–D1.1s Ask questions about observed relationships and plan investigations of questions, ideas, problems and issues by

- designing an experiment to show equilibrium shifts through colour change (**IP–STS3**) **[ICT C7–4.2]**
- designing a method to prepare a buffer (**IP–ST2**) **[ICT C6–4.1]**; and, e.g., by
- *identifying and illustrating the variables that can cause a shift in equilibrium* (**IP–NS2**) **[ICT C6–4.2]**

Performing and Recording

Students will:

30–D1.2s Conduct investigations into relationships among observable variables and use a broad range of tools and techniques to gather and record data and information by

- performing an experiment to test, qualitatively, predictions of equilibrium shifts (**PR–NS2, 3, 4, 5**) **[ICT C6–4.1]**
- investigating the relative abilities of a buffer and a control, i.e., water, to accommodate small amounts of acids or bases (**AI–NS6**) **[ICT C7–4.2]**; and, e.g., by
- *performing an experiment that illustrates equilibrium shifts through colour changes or precipitation* (**PR–ST2**) **[ICT C6–4.2]**

Analyzing and Interpreting

Students will:

30–D1.3s Analyze data and apply mathematical and conceptual models to develop and assess possible solutions by

- using experimental data calculate the equilibrium constant (**AI–NS1**) **[ICT F1–4.3]**
- analyzing, qualitatively, the changes in concentrations of reactants and products after an equilibrium shift (**AI–NS6**) **[ICT C6–4.2]**; and, e.g., by
- *explaining why there are limits to a buffered system* (**AI–NS4**) **[ICT C6–4.5]**

Communication and Teamwork

Students will:

30–D1.4s Work as members of a team in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results, e.g., by

- *working cooperatively with team members to develop an illustration and explanation of reversible reactions* (**CT–ST2**) **[ICT P6–4.1]**
- *using advanced menu features within a word processor to develop a group report on buffers and pH levels and uses* (**CT–STS2**) **[ICT P3–4.5]**

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 2: Determine quantitative relationships in chemical equilibrium systems.

Outcomes for Knowledge

Students will:

30–D2.1k Calculate equilibrium constants and concentrations for simple homogeneous chemical systems when
- concentrations at equilibrium are known
- initial concentrations and one equilibrium concentration are known
- the equilibrium constant and one equilibrium concentration are known

30–D2.2k Predict if reactions or products are favoured in a reversible reaction, on the basis of the magnitude of the equilibrium constant

Outcomes for Science, Technology and Society (Emphasis on the nature of science)

Students will:

30–D2.1sts Develop an understanding that technological development may involve the creation of prototypes and testing, as well as application of knowledge from related scientific and interdisciplinary fields (**ST1**), e.g.,
- *analyze, on the basis of chemical principles, the application of acids, bases, indicators and buffers in, e.g.,*
  - *processing and storage of food*
  - *medicine*
  - *the development of cleaning aids, pharmaceuticals and cosmetics*
  - *fertilizers and other industrial products*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 2: Determine quantitative relationships in chemical equilibrium systems.

Skill Outcomes (Focus on scientific inquiry)

Initiating and Planning

Students will:

30–D2.1s Ask questions about observed relationships and plan investigations of questions, ideas, problems and issues by

- designing an experiment to show equilibrium shifts in concentration(**IP–STS3**) [**ICT C7–4.2**]; and, e.g., by
- *designing an experiment to quantify a buffer capacity* (**IP–NS2**) [**ICT C6–4.2**]

Performing and Recording

Students will:

30–D2.2s Conduct investigations into relationships among observable variables and use a broad range of tools and techniques to gather and record data and information by

- performing an experiment to show equilibrium shifts in concentration (**PR–NS2**) [**ICT C6–4.1**]; and, e.g., by
- *performing an experiment to quantify a buffer capacity* (**PR–NS–2,3,4,5**) [**ICT C6–4.4**]

Analyzing and Interpreting

Students will:

30–D2.3s Analyze data and apply mathematical and conceptual models to develop and assess possible solutions by

- using experimental data to calculate equilibrium constants (**AI–NS1**) [**ICT F1–4.3**]; and, e.g., by
- *calculating the buffer capacity* (**AI–ST3**) [**ICT F1–4.2**]

Communication and Teamwork

Students will:

30–D2.4s Work as members of a team in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results, e.g., by

- *using advanced menu features within a word processor to develop a group report on equilibrium applications in Alberta industries* (**CT–STS2**) [**ICT P3–4.5**]

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.